Effect of Broadband Nature of Marine Mammal Echolocation Clicks on Click-Based Population Density Estimates

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LONG-TERM GOALS

The long-term aim of the project is to support passive acoustic monitoring (PAM) of Odontecetes.

OBJECTIVES

This project aims to demonstrate how the detection process of broadband clicks can be modeled for different marine mammal species and assess the magnitude of error on the estimated density due to various commonly used simplifying assumptions. Our main purposes are to quantify the bias in the population density estimate for selected species and detector due to use of the narrow band approximation in the computed propagation loss, and to understand the factors affecting the magnitude of this bias to enable extrapolation to other species and detectors.

APPROACH

Key individuals at TNO: Ainslie, von Benda-Beckmann
Key individuals at University of St Andrews: Thomas (CREEM), Tyack (SMRU)

Technical approach:

This project is in collaboration between TNO (PI: Michael Ainslie) with the University of St. Andrews (grant number: N000141410396, PI: Len Thomas).

Detectability of a broadband echolocation click is quantified by synthesizing pressure time series separately for noise $f_N(t)$, signal $f_S(t;r)$, and signal plus noise $f_{S+N}(t; r) = f_S(t;r) + f_N(t)$ (as illustrated in Figure 1). As a basis for the source echolocation clicks we intend to use recordings of echolocation clicks obtained nearby to the species considered in this study. These recorded source clicks are used to

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synthesize the corresponding echolocation clicks at the different ranges of interest, accounting for the effects of frequency dependent absorption on both propagation loss and detector performance. The resulting modeled received signal + noise are then fed through various detectors, thus enabling a high-fidelity estimation of the detection probability without recourse to the sonar equation. The detection probability will be established by repeating the process for multiple realizations of the noise.
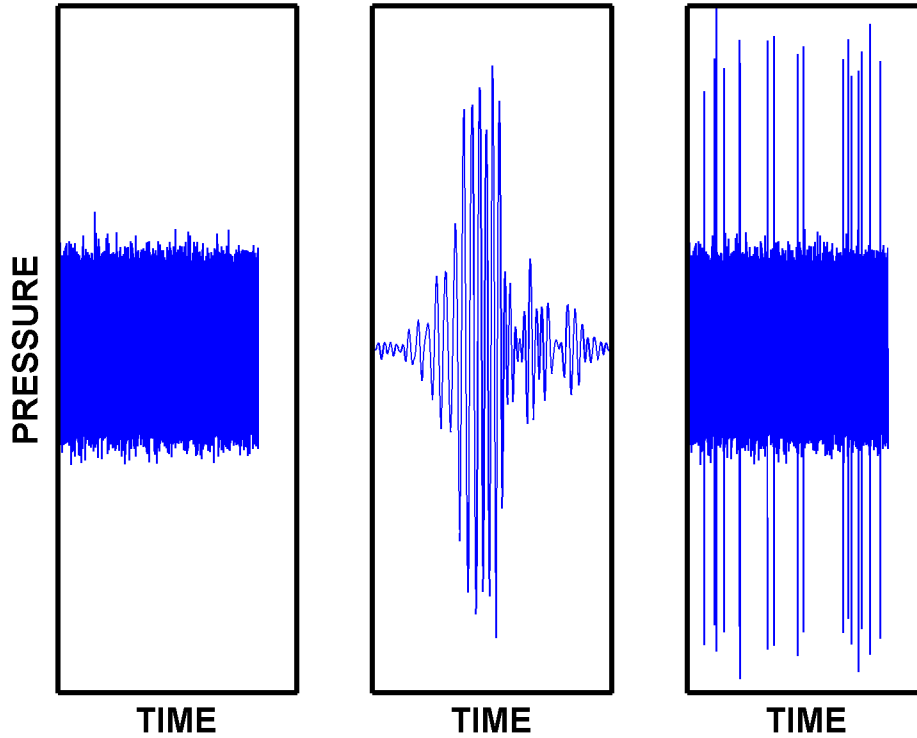

Figure 1 : Illustration of modeling procedure for generating test data for . Simulated echolocation clicks are generated through a Monte-Carlo approach by mixing recorded noise segments (left) with a synthesized signal waveform, which was propagated from near the source to a particular distance of the detector. The simulated test datasets are then run through various click detection algorithm to assess the detection probability and potential biases due to different propagation assumptions.

In this study we simulate the received click in the time domain for various echolocating marine mammal species. The research will focus initially on beaked whales (Blainville's or Cuvier's), for which high quality click recordings of clicks are available from DTAG data, as these are known to be sensitive to sonar sound, in a few cases leading to mass stranding, and therefore of high relevance to the US Navy. The same methodology will be applied also to other species such as sperm whale (*Physeter macrocephalus*) (whose high source level assures long range detection and amplifies broadband effects) and bottlenose dolphins (*Tursiops truncatus*) as a representative of a delphinid species with large bandwidth echolocation clicks.

The magnitude of the error caused by applying the conventional approach can be established at this stage by comparing detection probability computed for a broadband pulse with the approximation obtained with PL_{NB}. The magnitude of the density estimation errors due to various simplifications

using the passive sonar equation will be compared to other uncertainties introduced by variations in, e.g., click rate, group size, and click directionality.

WORK COMPLETED

The project kick-off meeting was held in July 2014.
Progress to date includes:

- reschedule project due to delayed start (new end date = April 1, 2015)
- approach various dataholders and collate suitable source click data
- inventorize common PAM detection algorithms
- adapt Matlab simulation platform used in von Benda-Beckmann et al. (2010) to work with various source signals and detectors.
- present progress at ESOMM 2014, Amsterdam (September 11, 2014)

RESULTS

There are no significant results to report from the first three months of this study. An inventory of common PAM detection algorithms to be considered as representative detection models are listed in Table 1.

Table 1 : Inventory of common detection algorithms used in PAM applications
for detecting marine mammal echolocation clicks.

Detector	Reference
Pamguard Click detector	Gillespie and Leaper (1995)
FFT energy band detector	Ward et al. (2008)
Power-Law Page test detector	Van IJsselmuide and Beerens (2004)
Matched-filter detector	Ward et al. (2008)
Teager-Kaiser (TK) click detector	Kandia and Stylianou (2005)
Ishmael energy sum click detector	Yack et al. (2010), Mellinger (2001)
Energy Ratio mapping	Klinck and Mellinger, (2011)

IMPACT/APPLICATIONS

Estimates for the abundance of marine mammals are required for the assessment and effective mitigation of the impact of naval activities, such as sonar or underwater detonations, on marine mammals. Obtaining reliable and unbiased abundance estimations of marine mammals is essential, because in environmental impact assessments a bias would cause an under- or over-estimate of the number of marine mammals affected by naval activities.

The proposed study will result in guidance on the species and conditions for which a simplified use of the passive sonar equation can be used to obtain unbiased population density estimation, or for which more elaborate and time-consuming modeling of the click propagation and detection is required. Such guidelines could then be used for ongoing and future PAM projects that rely on detection of broadband echolocation clicks.

It is expected that the method developed in the proposed study will improve the accuracy of marine mammal density estimation based on counting echolocation clicks, and will be applicable to density estimates obtained using different PAM-approaches, including bottom-mounted/ deployed hydrophones and line transect surveys.

RELATED PROJECTS

Effect of broadband nature of marine mammal echolocation clicks on click-based population density estimates (grant number: N000141410409, PI: Michael Ainsle, TNO).

REFERENCES

Gillespie, D. and Leaper, R. (1996). Detection of sperm whale Physeter macrocephalus clicks and discrimination of individual vocalizations. European Cetacean Research. Abstracts, pp. 10:87–91.

Kandia, V., and Stylianou, Y. (2005). Detection of sperm whale clicks based on the Teager–Kaiser energy operator, Applied Acoustics, 67: 1144–1163.

Mellinger, D.K. (2001) Ishmael 1.0 user's guide, NOAA Technical Memorandum OAR PMEL.

Klinck, H. and Mellinger, D.K. 2011, 'The energy ratio mapping algorithm: A tool to improve the energy-based detection of odontocete echolocation clicks', The Journal

van IJsselmuide, S.P. and Beerens, S.P. (2004). Detection and classification of marine mammals using an LFAS array. Canadian Acousics 32, 4.

von Benda-Beckmann A.M., Lam F.P.A., Moretti D.J., Fulkerson K., Ainslie M.A., van IJsselmuide S.P., Theriault J., and Beerens S.P. (2010). Detection of Blainville's beaked whales with towed arrays. Applied Acoustics 71:1027–1035.

Ward, J.A., Thomas, L., Jarvis, S., DiMarzio, N., Moretti, D., Marques, T.A., Dunn, C., Claridge, D., Hartvig, E. and Tyack, P. (2008). Passive acoustic detection and localization of *Mesoplodon Densirostris* (Blainville's beaked whale) vocalizations using distributed bottommounted hydrophones in conjunction with a digital tag (DTag) recording, Canadian Acoustics, 36 (1):60-66.

Yack, T.M., Barlow, J., Roch, M.A., Klinck, H., Martin, S., Mellinger, D.K. & Gillespie, D. 2010, 'Comparison of beaked whale detection algorithms', Applied Acoustics, vol. 71, no. 11, pp. 1043-9.